

Structural Health Monitoring of Aircraft Wing Using Wireless Network

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Abstract—The usage of composites in aircraft industry has enormously increased over the past few decades and has led to the development of modern trends. This improves the cutting edge technology which provides an outsourcing service from designing to manufacturing. This study is concerned with the detection and characterization of hidden defects in composite structures before they grow to a critical size. Its immediate application is in the health monitoring of aircraft structure in order to detect crack, corrosion and fatigue stress-strain. A methodology for damage identification is developed by using Lamb wave propagations. Lamb wave techniques provide more information about damage presence and severity than previously tested methods (Frequency Response Techniques). A piezoelectric actuators and sensors network could fulfill the required monitoring tasks concerning fatigue, damage (or) stress of structural parts. A six layered glass fiber composite was manufactured with piezoelectric (PZT) sensors embedded on it. The specimen was tested for wireless network for data transmission and was found successful.

Keywords: Composites; Structural Health Monitoring System; Lamb wave; Frequency Response Techniques; piezoelectric actuators.

I. INTRODUCTION

The process of implementing a damage identification strategy for aerospace, civil and mechanical engineering infrastructure is referred to as structural health monitoring (SHM). Here, damage is defined as changes to the material and/or mechanical properties of a structure, including changes to the boundary conditions, which adversely affect the structural performance. A wide variety of highly effective local non-destructive evaluation tools are available for such monitoring. However, the majority of SHM research conducted over the last 30 years has attempted to identify damage in structures on a more global basis. The past 10 years have seen a rapid increase in the amount of research related to SHM and its associated potential for significant life-safety and economic benefits has motivated the need for further development. [1]

Structural Health Monitoring (SHM) aims to give, at every moment during the life of a structure, a diagnosis of the “state” of the constituent materials, of the different parts, and of the full assembly of these parts constituting the structure as a whole. The state of the structure must remain in the domain specified in the design, although this can be altered by normal aging due to usage, by the action of the environment, and by accidental events.

II. SYSTEM ARCHITECTURE

The proposed strategy for an SHM system is to integrate both usage and damage detection in order to emphasize that both aspects are necessary and they complement each other.

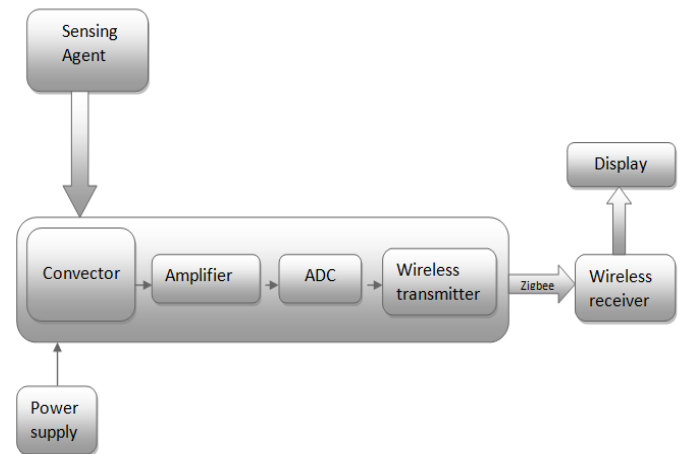


Figure 1. Functional Block Diagram of Structural Health Monitoring of Aircraft wing

III. EXPERIMENTAL PROCEDURE

A wireless sensor network is an emerging research area with application in many fields. In this chapter, we have described in detail the architecture of a wireless sensor network which can be used to monitor the health of aircraft wing.

A. Fabrication of Glass Fiber Composite:

Fiberglass also called glass-reinforced plastic, GR Pglass-fiber reinforced plastic, or GFRP is a fiber reinforced polymer made of a plastic matrix reinforced by fine fibers of glass. Fiberglass is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. The plastic matrix may be epoxy, a thermosetting plastic (most often polyester or vinyl ester) or thermoplastic.

B. Fabrication of Glass Fiber Composite with PZT

There are different methods of manufacturing glass fiber. A glass fiber of 30x15(cm) was fabricated using manual operation or fiber glass hand layup operation. A six layered fiber glass composite was constructed embedding the PZT patches in between the third layer of the glass fiber. A release agent, usually in either wax or liquid form, is applied to the chosen mold. This will allow the finished product to be removed cleanly from the mold. Resin –Araldite GY257– is mixed with its hardener as per the ration mentioned above and applied to the surface. Sheets of fiber glass matting are laid into the mold, then more resin mixture is added using a brush or roller. The material must conform to the mold, and air must not be trapped between the fiberglass and the mold. Additional resin is applied and possibly additional sheets of fiberglass. Hand pressure, vacuum or rollers are used to make sure the resin saturates and fully wets all layers, and any air pockets are removed.



Figure 2. Glass Fiber Composite Embedded with PZT Patches

PZT patches are placed in the third layer and the process is continued until sixth layer. The work must be done quickly enough to complete the job before the resin starts to cure, unless high temperature resins are used which will not cure until the part is warmed in an oven. In some cases, the work is covered with plastic sheets and vacuum is drawn on the work to remove air bubbles and press the fiberglass to the shape of the mold. PZT ceramic is used in a wide variety of applications. Soft (sensor) PZT ceramic powders are typically used when high coupling and/or high charge sensitivity are important, such as in flow or level sensors; ultrasonic non-destructive testing/evaluation (NDT/NDE) applications; or for accurate inspections of automotive, structural or aerospace products. Material characteristics include a high dielectric constant; high coupling; high charge sensitivity; high density with a fine grain structure; a high Curie point; and a clean, noise-free frequency response.

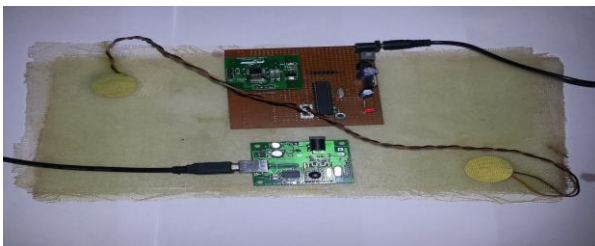


Figure 3. PZT Sensor with Wireless Module

A six layered glass fibre composite was manufactured with PZT sensors embedded on it. The specimen was tested for wired and wireless networks for data transmission and was

found successful. The circuit diagram along with all specifications and the microcontrollers used are explained in detail.

IV. RESULT AND DISCUSSION

Analysis was performed on the plate to determine the ultimate strength, the reason being the maximum stress of plate and maximum strain will facilitate in determining the amount of strength the plate can withstand and above which is considered to be hazard limit for real time conditions. Loading conditions for glass fiber composite plate in NASTRAN. The (30cm*15cm) glass fibre composite plate is segmented into 136 nodes as nodal displacement. It is assumed that plate is fixed at one end and load is applied on transverse axis or perpendicular axis of the plate and since the impact is throughout the plate the load condition is considered as uniformly distributed load. So when shear force exceeds the maximum limit the bending moment attains zero taking these factors into account 5KN of load is applied as input load throughout the plate.

The resultant is shown in the form of stress, strain values.



Figure 4. Stress on layer 1

This graph shows the maximum stress is developed at node 56 and minimum strain developed is at node 69 with von-mises stress condition.



Figure 5. Stress on layer 3



Figure 6. Stress on layer 6

The Von Mises yield criterion shows that the yielding of material begins when the deviatoric stress invariant reaches a critical value. The above image shows the maximum stress is developed at node 56 with a stress value of 1.52KPa and minimum developed is at node 69 with 1.48KPa. The stress is

spread throughout the plate and the maximum amount induced is represented in red colour code and least induced with blue colour code. Since it is fixed at one end considering the wing condition of an aircraft the stress is maximum on all six layers.

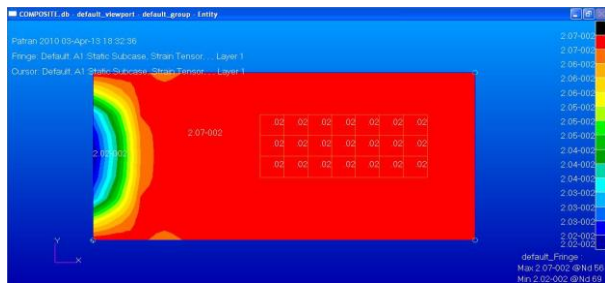


Figure 7. Strain on layer 1



Figure 8. Strain on layer 3

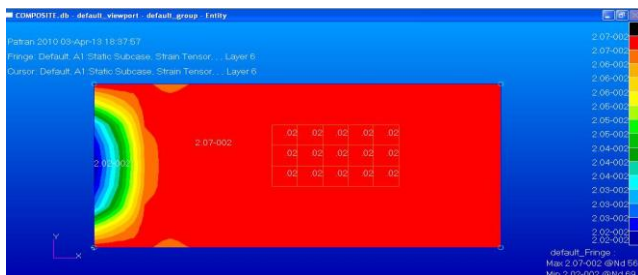


Figure 9. Strain on layer 6

The above images show that maximum strain is developed at node 56 with a value of 2.07×10^{-3} m and minimum developed at node 69 with 2.02×10^{-3} m. All six layers of the plate have same amount of deformation due to invariable load condition. The fixed end has least deformation than free end since load acting is endured extensive on free surface pertaining to wing condition of the aircraft.

V. CONCLUSION

The approach of using embedded ultrasonic guided wave transducer network and a wireless structural health monitoring device for aircraft wing inspection has been studied. The ultrasonic data can be collected on-board the wing and sent out wirelessly to a local PC. The signal quality is good and can also be used for defect detection and localization. Experimental tests were carried out for a fully embedded system with PZT sensor. Defect detection and location estimation were not successfully demonstrated but the level of ultimate stress in the material was determined with varying results which facilitated in plotting the stress vs. displacement curve and with help of NASTRAN analysis, maximum stress and minimum strain were found.

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